Modified Biopolymers as an Alternative to Petroleum-based Polymers for Soil Modification.

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ERDC-Environmental Laboratory

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Greg O'Connor – ARDEC

Introduction

Rhizobium tropici is a catalogued symbiotic nodulator of leguminous plants. It produces a gel-like, extracellular polymeric substance (EPS).

The natural functions of the EPS include surface adhesion, self-adhesion of cells into biofilms, formation of protective barriers, water retention and nutrient accumulation around roots. These properties can be exploited for many varied military and civilian uses.

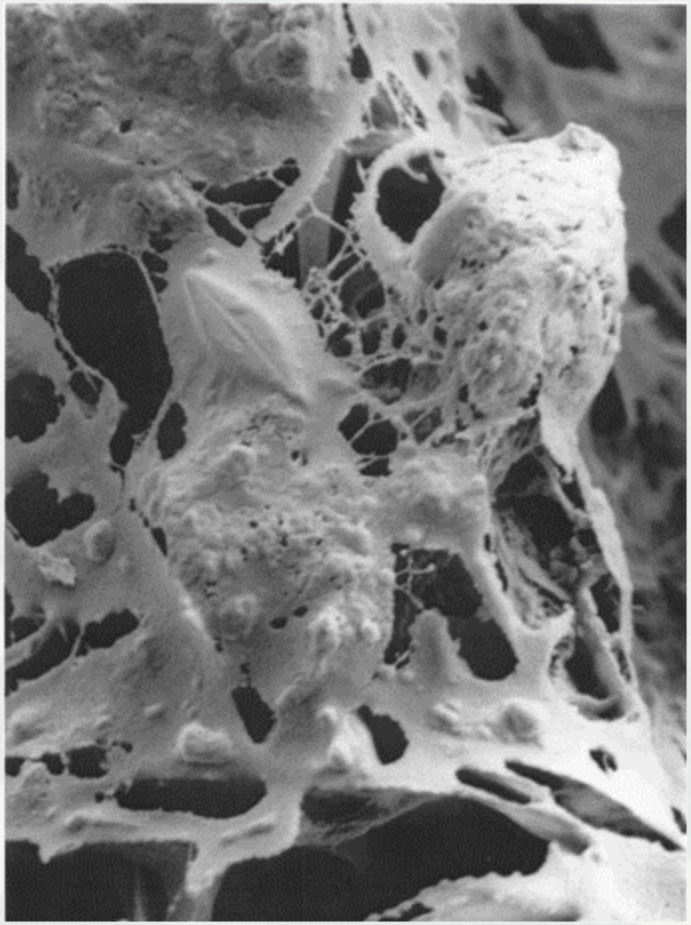
SAFR Range Sustainability

- Environmental
- Operations and Maintenance

Soil Modification through Biopolymer Amendment

Individual soil particles are linked together within the biopolymer matrix. This reduces their mobility which results in :

- Erosion Control
- Reduction of Suspended Solids
- Reduction in Heavy Metal Transport
- Increase in Strength of the Soil Surface Layer



Scanning electron micrograph of sediment surface coated with EPS. (Black et al. 2002)

- Cross-linkages offered by embedded EPS encourage soil particle aggregation and contribute to erosion control and soil stability

- Biomimetic technology using EPS of terrestrial bacterial origin, takes advantage of natural functions of soil adhesion, water retention, biofilm strength, and persistence in the soil.

Advantages of the biopolymer over petroleum-based polymers (COTS)

- Fewer Logistical Concerns
  - Less material, less mixing
  - Eliminate the generation and transport of hazardous products and by-products

- Smaller Footprint
  - Not petroleum-based
  - Renewable
  - Natural component of most soils they are considered environmentally benign

Biopolymer Structure

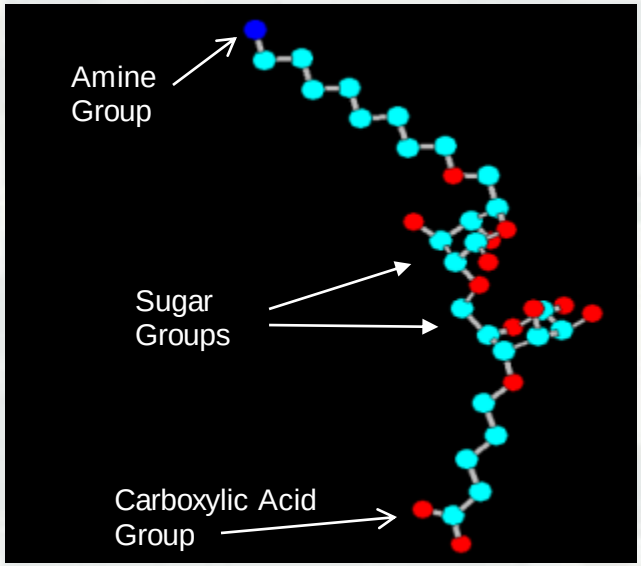
Both synthetic and biopolymers have a “primary structure” of repetitive monomeric units.

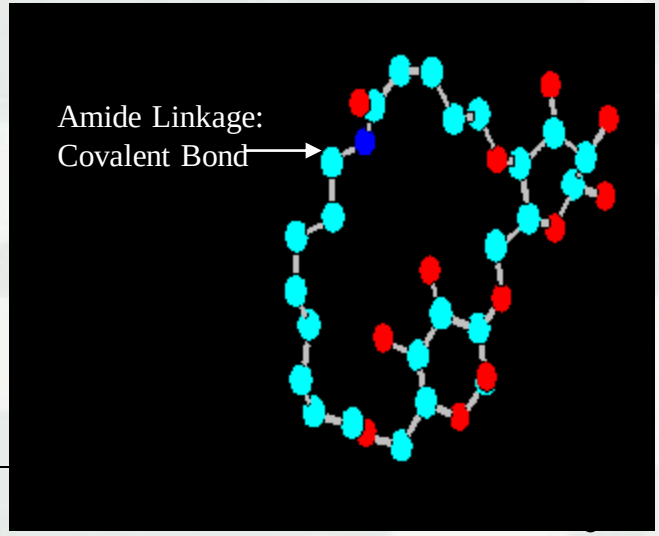
<u>Synthetic polymers</u>:

- ►Simpler, less varied structure

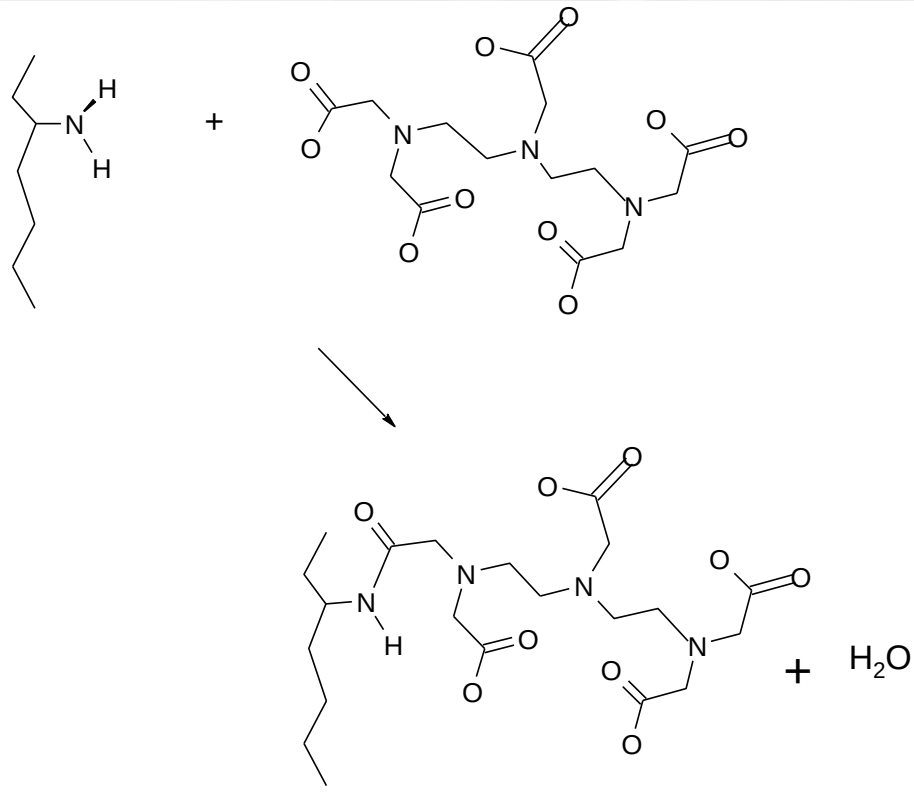
<u>Biopolymer:</u>

- ►more complex
  - Folding, crosslinkages changes shape and chemical properties
  - Complex pendant moieties that display highly specific functionalities.





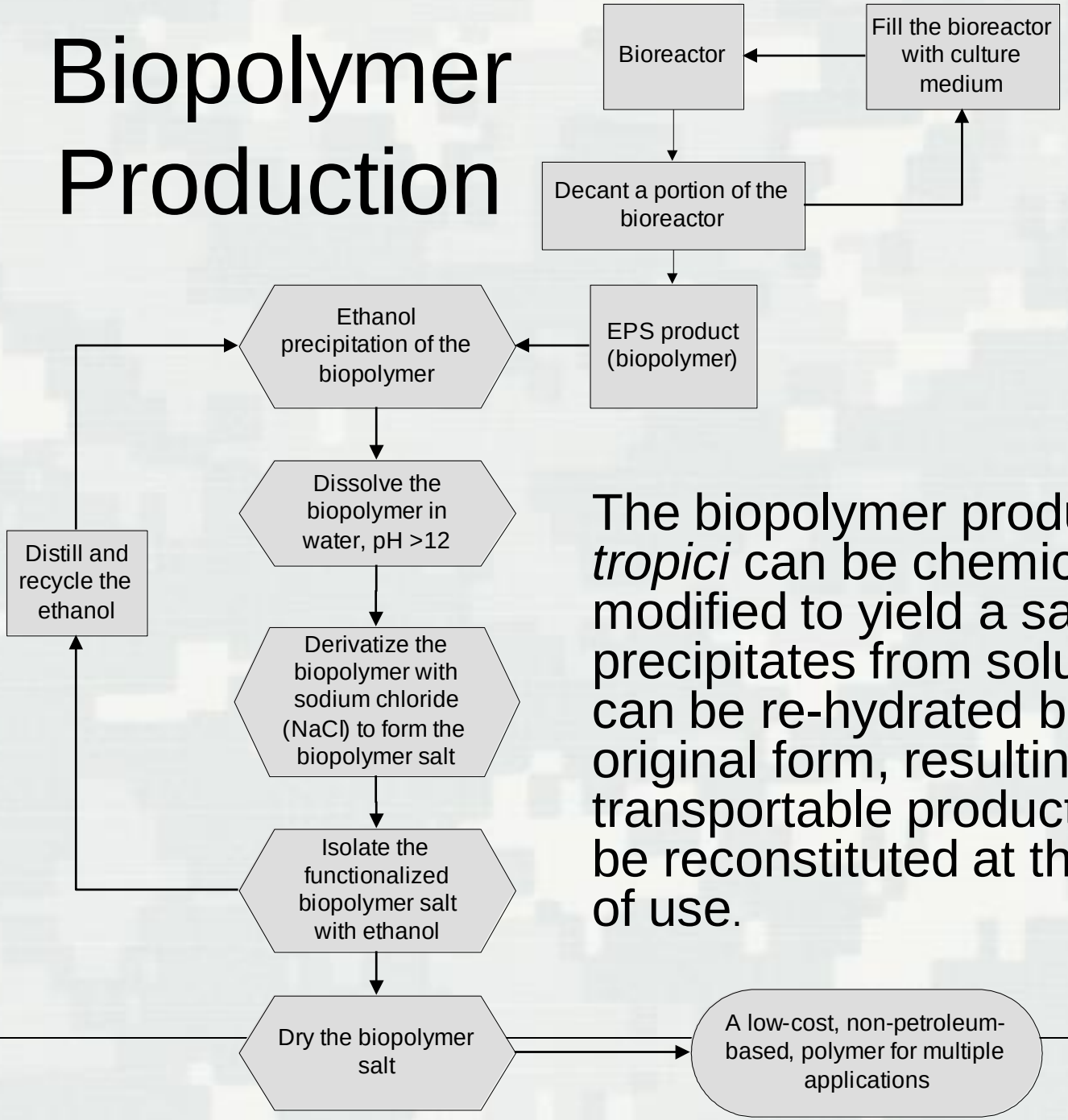
Synthesis



Sequestration of heavy metals through the use of biopolymers modified with chelating groups

Carboxyl group of DTPA reacts with biopolymer amino group releasing water in a dehydration (condensation) synthesis. Derivative is a polydentate ligand for metals sequestration.

Biopolymer Production

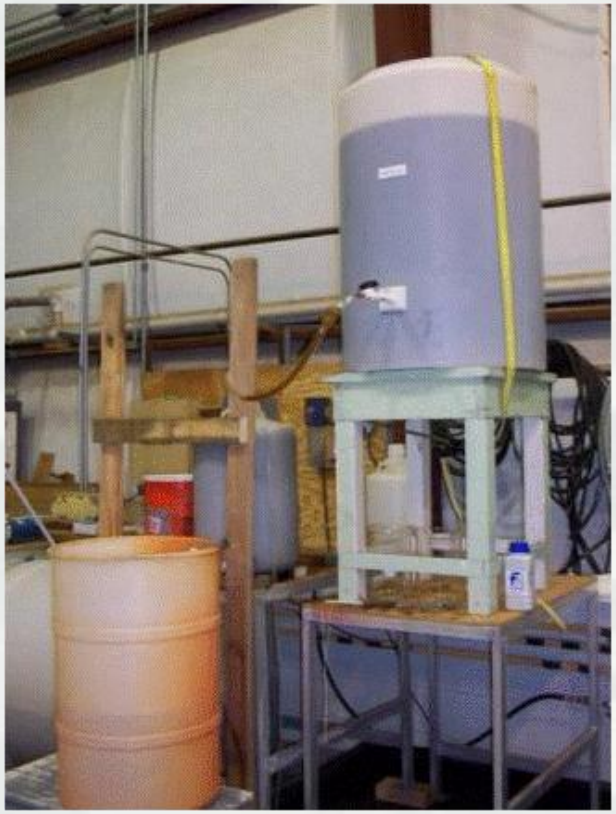


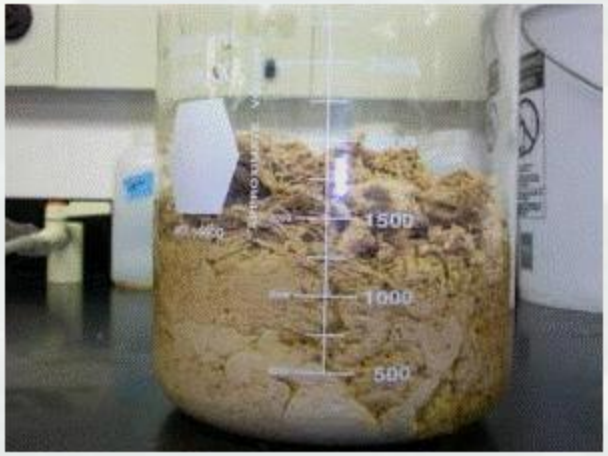
The biopolymer produced by *R. tropici* can be chemically modified to yield a salt that precipitates from solution and can be re-hydrated back to its original form, resulting in a transportable product that can be reconstituted at the location of use.

Optimization through manipulation of growth medium, temperature, oxygen flow, and bioreactor pH

Biopolymer Production Process

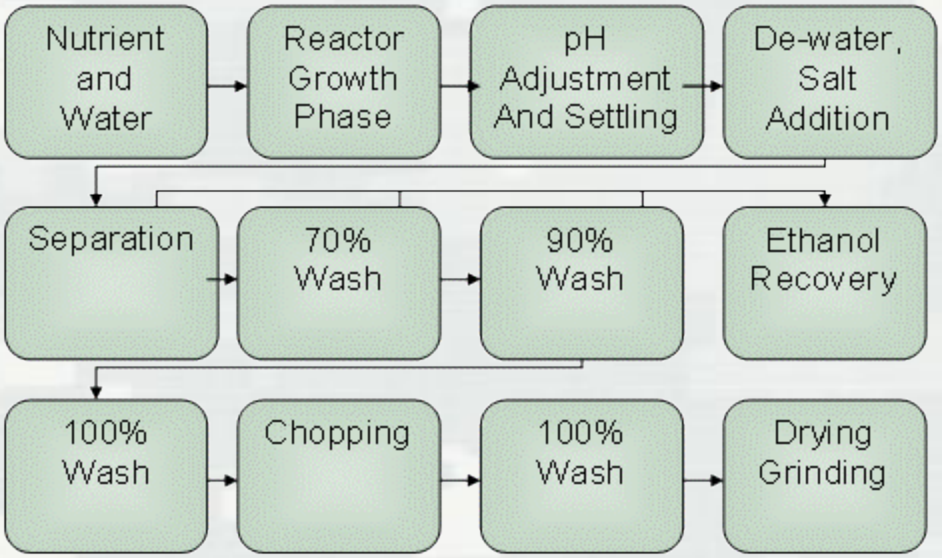
Production has gone from bench-scale to pilot-scale. We can now make kg of biopolymer each week for testing of new and varied applications, both military and civilian.





Biopolymer Production

Schematic of biopolymer production process



Older reactor (400 gal, left) and newest reactor (800 gal, right)

The cost driver of the production process was determined to be the ethanol usage and energy costs associated with re-distillations of the used ethanol. Process modifications have been introduced to reduce the ethanol usage by a factor of 20.

Biopolymer Production
Soil Amendment

Final Product

A finely-ground dry biopolymer salt ready to be added to soil.

Soil Amendment

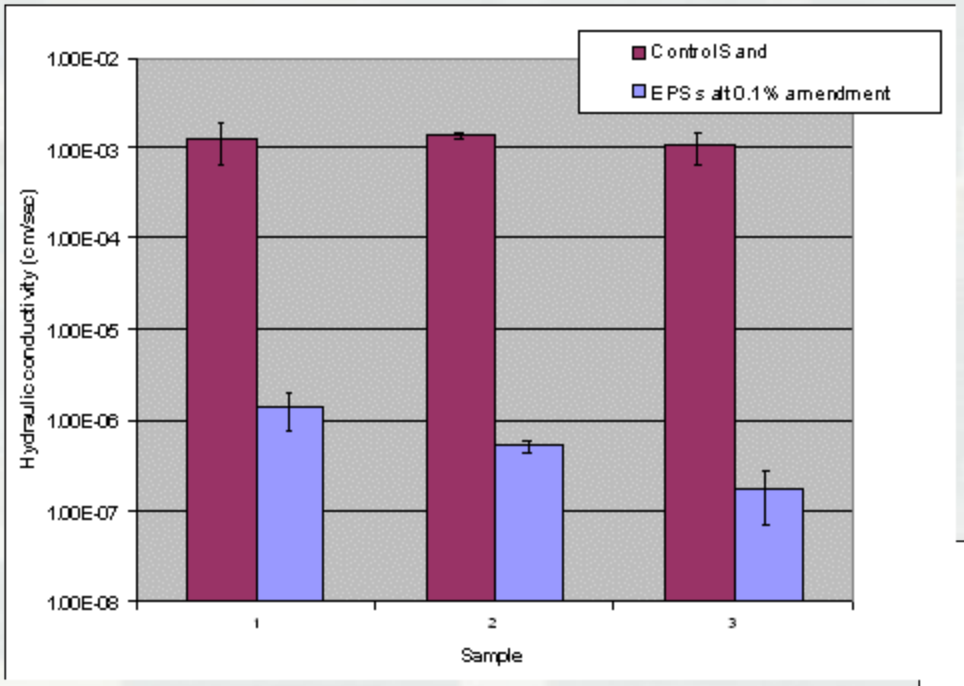
Dry addition: Add dry biopolymer to the soil, mix well (manually), add any non-potable water and allow to dry.

Wet addition: Mix dry biopolymer with non-potable water and mix well. The solution will become thick. Apply the gel mixture to the soil using a standard sprayer. Allow the soil to dry. Repeat the process several times to get the most complete coverage.

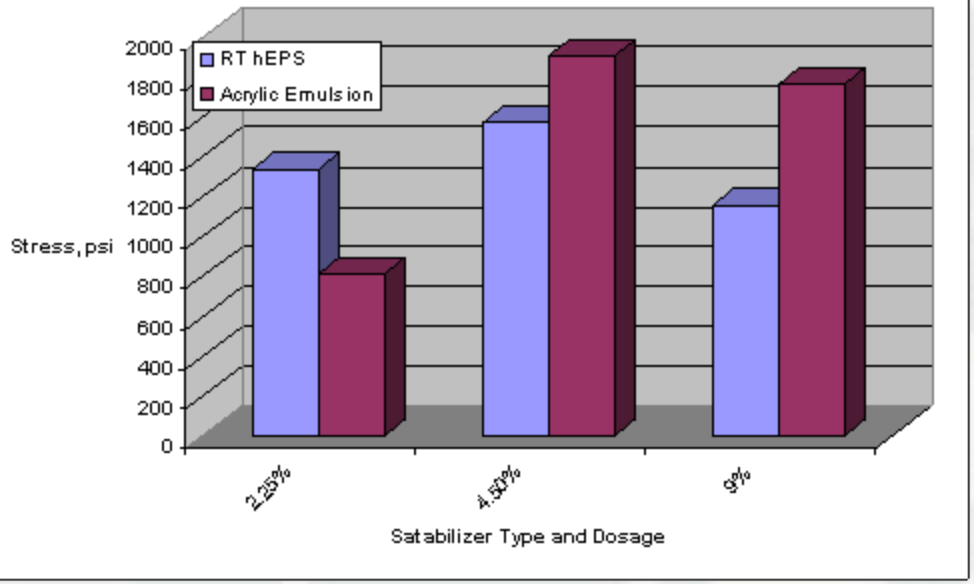
Biopolymer required for 0.2% mass loading

Treatment depth (inches)	gr BP /yd^2	Kg BP /acre	Kg BP / hectare
1	56	7	17
3	168	21	50
8	448	54	132
18	1.0 kg	120	295

Results: Bench-scale study – Geotechnical



Comparison of hydraulic conductivity in a silty sand soil.

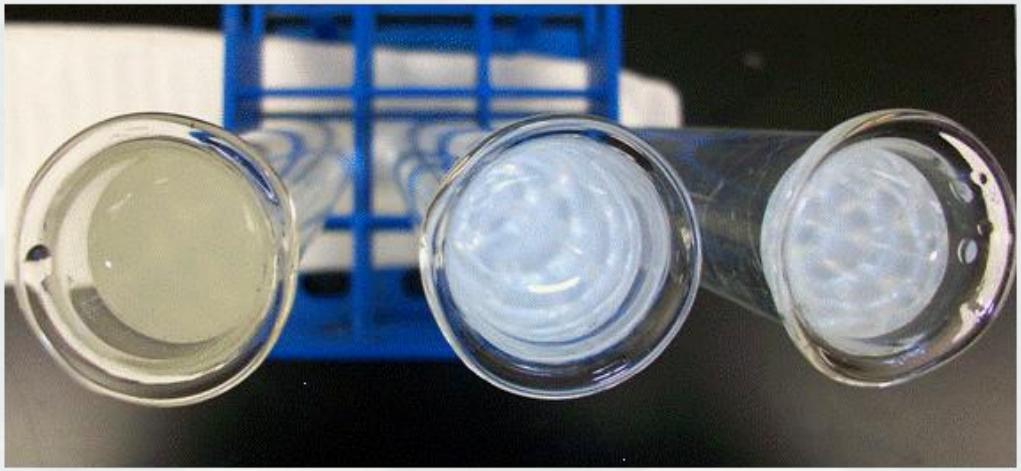


Comparison of peak stress for unconfined compressive tests in a silty sand soil.

Erosion Study – Suspended Solids and Turbidity

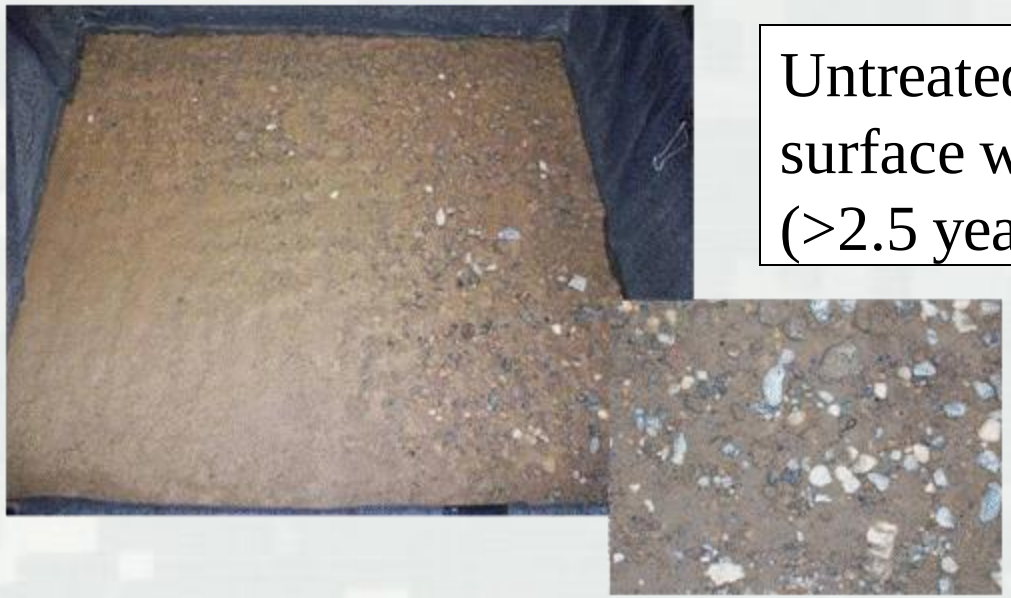
- The appearance of surface runoff water from soil treated at increasing loading rates of biopolymer.
- Higher loading rates demonstrate decreased suspended solids and turbidity.

Biopolymer % by soil weight:	0.0	0.10	0.20



Turbidity of water Post settling:	19 NTU	6 NTU	4NTU

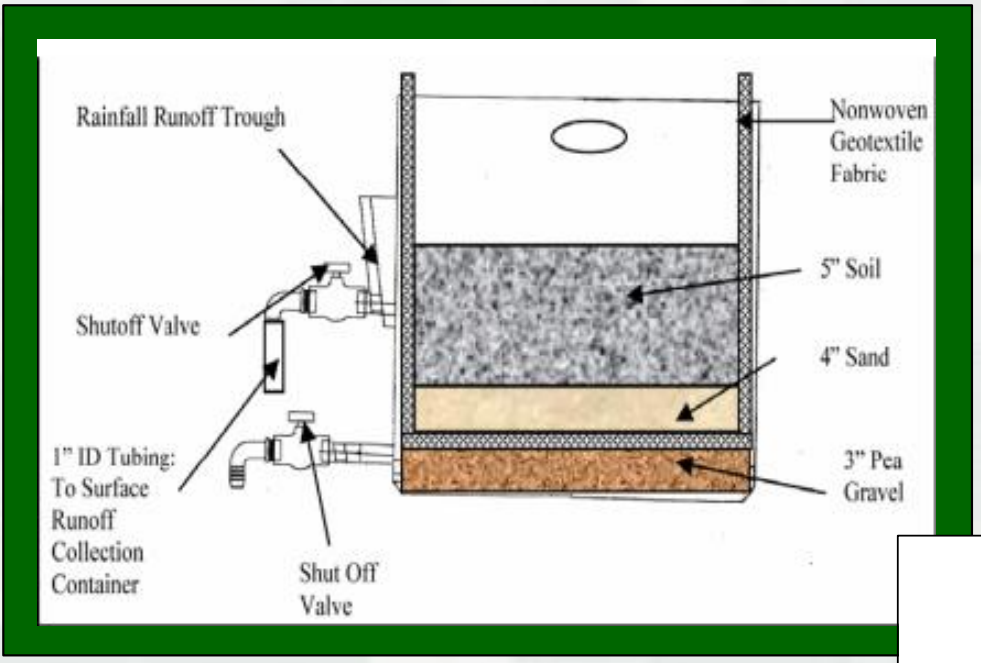
Static Lysimeter Cells – Erosion Control



Untreated soil. Exposed gravel due to surface water runoff after 19 rain events (>2.5 year rainfall).

Biopolymer-treated soil demonstrating surface durability and resistance to erosion after 19 rain events (>2.5 year rainfall).

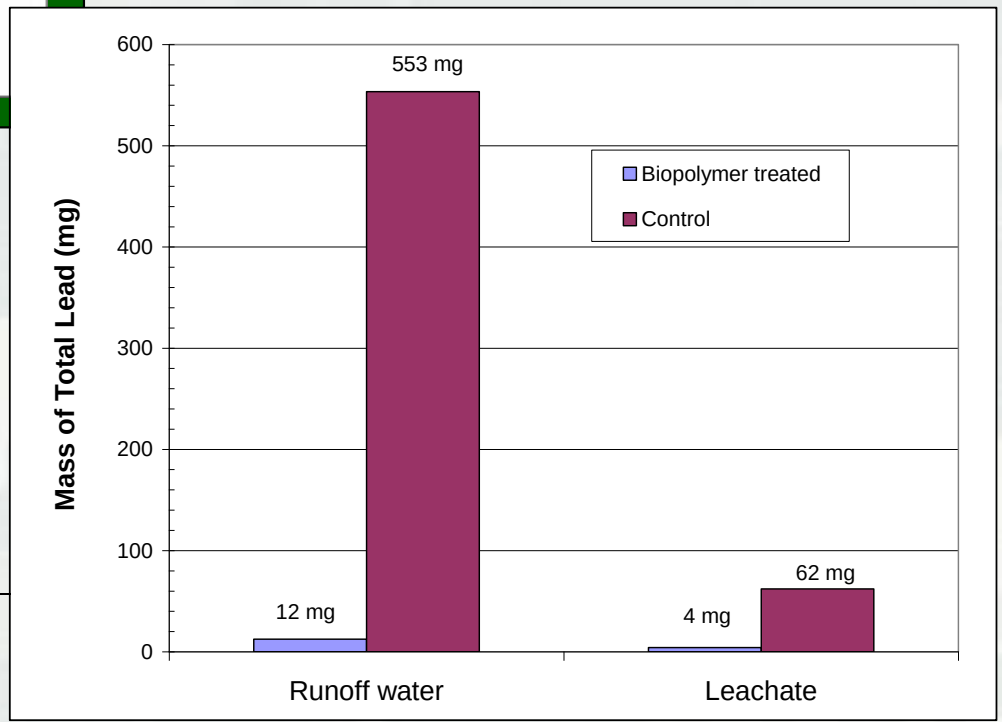
Performance Objectives – Metal Stabilization



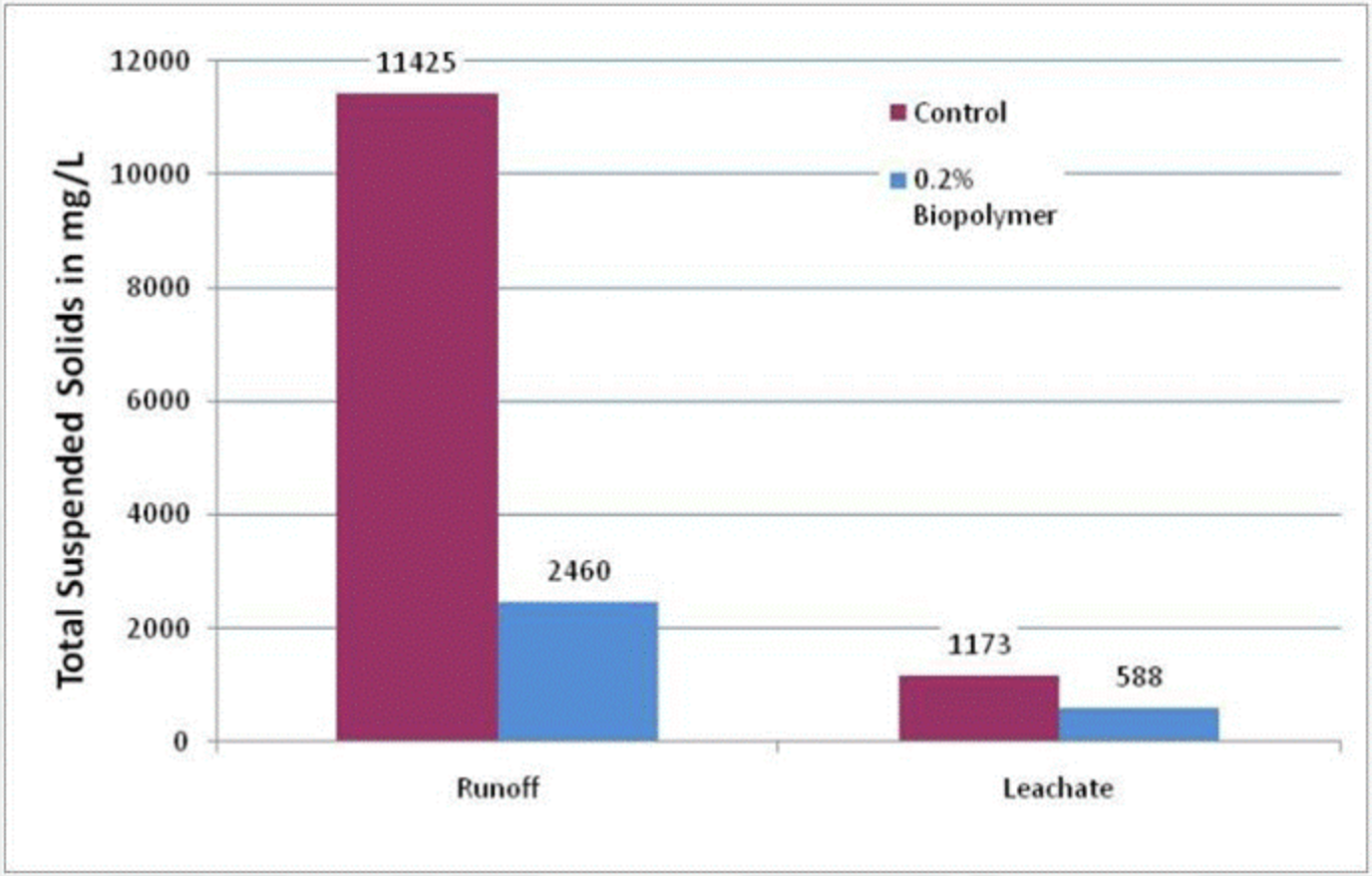
These results are from the use of the unmodified biopolymer in soil.

Simulated weathering time = 2.5 years

Rainfall based on average Southeast rainfall of 47-51 inches per year.



Performance Objectives – Soil Stabilization



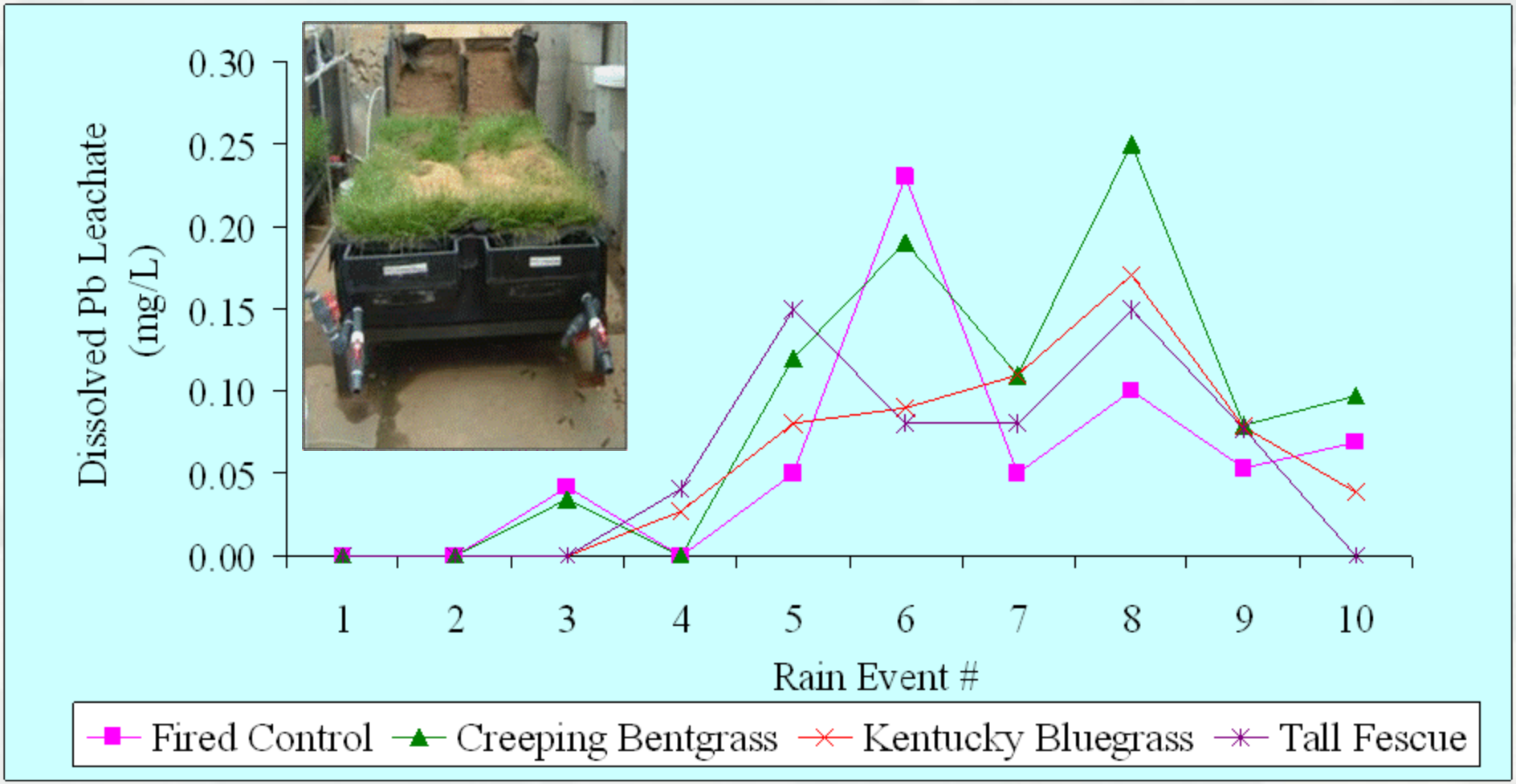
Simulated weathering time = 2.5 years

Rainfall based on average Southeast rainfall of 47-51 inches per year.

Vegetative Range Floor– TSS/ Runoff Control

Live-fire Lysimeters

Vegetated Range Floor Enhanced Pb Leaching



Operations and Maintenance– Erosion Control and Slope Stability

Loess (Silt) soil type

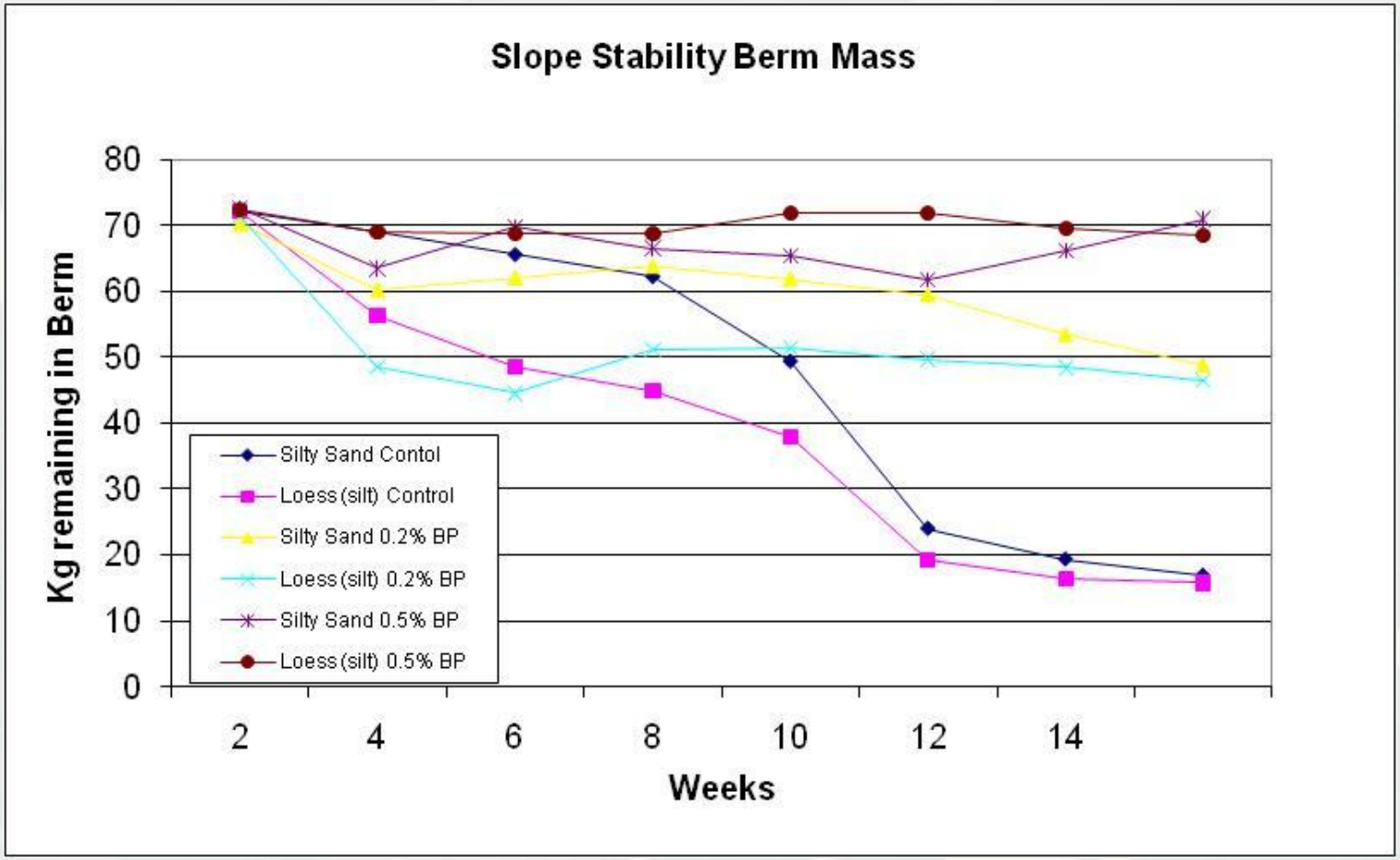
Control

0.0% biopolymer

0.2% biopolymer

0.5% biopolymer

Performance Objectives – Erosion Control and Slope Stability



Summary

The potential advantages of the biopolymer over conventional petroleum-based polymers as a soil amendment are:

- decreased soil loss through reduced erosion,
- reduced berm maintenance costs,
- ease of storage and use,
- decreased potential for transport of particulates (such as heavy metals) in water (suspended solids) and in air (fugitive dust).
- decreased carbon footprint in production of the biopolymer,
- it is a “green” technology that reduces/eliminates the use of/generation of hazardous substances in its production,
- Increase in public acceptance of the soil treatment.
- Reduced use within the DoD of petroleum-based compounds

Questions ?